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Developed Computerized Tools Based on Mental Models for Creativity Support

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Abstract

Recently, creativity has become a hot spot of research in the wide area of academy and industry. The recognition of the definition or nature of creativity and the computerized tools for creativity support are two research perspectives. The latter as the common approach has got more and more attentions from multi-disciplines, such as cognitive psychology, management science, system science, knowledge science, social science and computer science, etc. Also, both the theory and mental models have been involved in the design and operation of the computerized tools. This paper presents a creativity support system, named group argumentation environment (GAE) which is a platform for idea generation, knowledge creation and wisdom emergence by versatile aids, like visualization of expert opinion structure, clustering of contributed opinions for concept formation and idea/knowledge detecting and growing, etc.

Keywords: Creativity, Mental model, Creativity support system, Group argumentation

1. Introduction

Guilford stressed creativity with a presidential address to the American Psychological Association in 1950, and creativity is becoming the heart of the quest for competitive advantage and organizational survival. So, more and more scientists pay attention to the research of creativity from different research interesting and perspectives, such as cognitive psychology, management science, system science, knowledge science, social science and computer science, etc. Many approaches can be traced with two main lines, one is about the defining the nature of creativity itself through giving anecdotal descriptions and analyzing creativity by cognitive experiments to answer the following questions: What is creativity? What are the cognitive, personality, and motivational constituents of creativity? What is the role of social context in creativity, etc? The other research is on building computerized tools support creativity, named creativity support systems which use information technology to understand and enhance creativity and emphasize how the environment be designed to effectively and efficiently exploiting individuals' implicit knowledge, externalizing their mental models, and stimulating their intuition, insight and creativity. It is our research area. We concentrate on computerized collaborative support for enhancing human's creativity during argumentation process. Versatile computerized aids have been developed, such as visualization of expert opinion structure, clustering of contributed opinions for concept formation and idea/knowledge detecting and growing, etc. all integrated into a group argumentation environment (GAE).

This paper gives a brief recognition of creativity and its theories in the first section. Some typical mental models and creativity support tools will be presented in the second and third sections. Section 4 mainly introduces the features and functions of GAE, which supports group divergent thinking for creativity emergence. The last section is the conclusion and future work.

2. Recognition of Creativity

Creativity is a topic of wide scope for a wide range of domains. The meaning of creativity itself is very vague, even obscure. But, creativity is very important

for daily life, which is the ability to produce work that is both novel and useful, and has been widely employed for many realms, such as art, science, design, etc., particularly in education. It is thus that more and more researchers are concerned with creativity to meet the challenge. To date, the study of creativity steps from mystical approaches, pragmatic approaches, psychodynamic approaches, psychometric approaches, cognitive approaches and social-personality approaches to confluence approaches [1]. It demonstrates creativity never been one of psychology's orphans, what's more, which integrates the factors of motivation, culture, environment, society and shows a trend of diversified development. The following table summarizes the representative figures and theories of each approach.

More attentions are paid to the above cognitive or social creativity theory, more mental models are built and constructed as one of the most available and effective form and approach for creativity applying. So, the following will be introduced some typical mental models.

Table 1. Representative figures and theories of each approach

Approaches	Representative figures	Claims/Theories
mystical approaches	Kipling, 1937 Ghiselin, 1985	The creative person was seen as an empty vessel that a divine being would fill with inspiration. The individual would then pour out the inspired ideas, forming an otherworldly product.
pragmatic approaches	De Bono, 1971 Osborn, 1953 Gordon, 1961	Whose concern is not with theory, but with practice. Some creative methods and skills was developed, such as brainstorming, synectics, etc.
psychodynamic approaches	Freud, 1908 Kris, 1952 Kubie, 1958	Based on the idea that creativity arises from the tension between conscious reality and unconscious drives.
psychometric approaches	Guilford, 1950 Torrance, 1974	Creativity could be studied and tested by fluency (total number of relevant responses), flexibility (number of different categories of relevant responses), originality (the statistical rarity of the responses) and elaboration (amount of detail in the responses).
cognitive approaches	Finke, 1995 Weiberg, 1986	Creativity seeks to understand the mental representations and processes underlying creative thought.
social-personality approaches	MacKinnon, 1965 Barron, 1968 Gough, 1979 Eysenck, 1993	Who noted that certain personality traits often characterize creative people. These traits include independence of judgment, self-confidence, attraction to complexity, aesthetic orientation, and risk taking.
confluence approaches	Amabile,1983 Sternberg&Lubart, 1995 Csikzentmihalyi, 1988 Gardner, 1993 Woodman, 1993 Ford, 2002	The Componential Theory of Creativity Investment Theory of Creativity Three-pronged Systems Model of Creativity Interaction Approach Interactionist Theory of Creativity Multiple Social Domain Theory

3. Mental Models

A Mental model is a representation of some domain or situation that supports understanding, reasoning and prediction. Mental models permit reasoning about situations not directly experienced. They allow people to mentally simulate the behavior of a system. Some typical mental models have been proposed.

3.1 Wallas's four stages model

The western, individual model of creativity was first articulated by Graham Wallas in his 1926 book The Art of Thought [2]. Wallas's model has four stages as show in Fig 1, which constantly overlaps each other as we explore different problem, even the same problem.

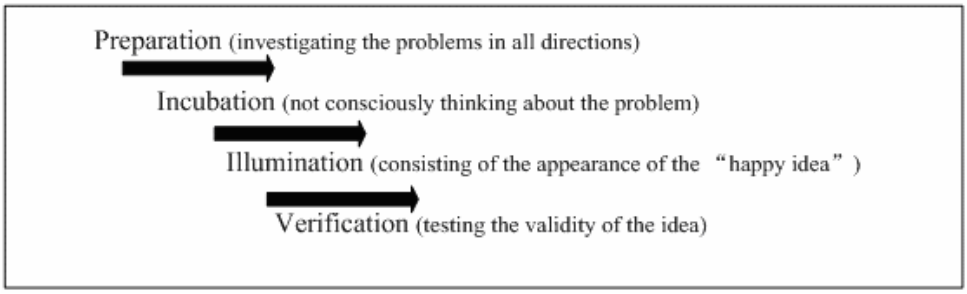

Fig. 1. Wallas's four stages model

3.2 Geneplore model

Geneplore is a model of multiple processes of creativity which was proposed by Finke in 1992[3]. There are two phases as shown in Fig 2: a generative processes and exploratory processes. In the generative processes, an individual constructs mental representations referred to as preinventive structure which has properties promoting creative discoveries such as memory retrieval, association, mental synthesis, mental transformation and analogical transfer, etc. The properties like attribute finding, conceptual interpretation, functional inference and contextual shifting are used by creative thinkers to come up with creative ideas in the exploratory phase.

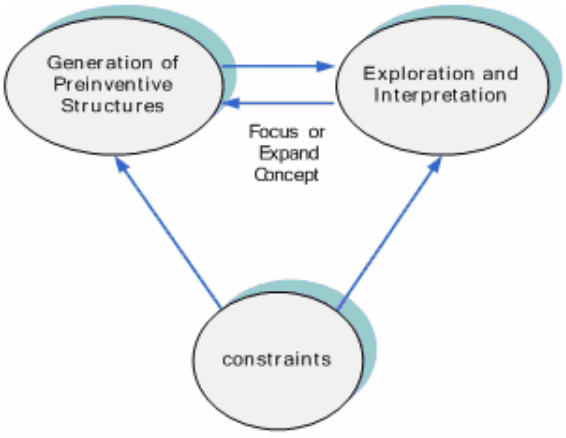

Fig. 2. Geneplore model

3.3 Boden's creative model

Boden defines and explains creativity in terms of the mapping, exploration, and transformation of structured conceptual spaces [4]. A conceptual space is a style of thinking which has various dimensions, limits, pathways, and levels. To overcome a limitation in a conceptual space, one must change it in some way, and a large change can be caused by a transformation. She shows two general ways of transforming conceptual space: to drop a constraint, and to negate a constraint. Boden's creative model has a great impact on the field of artificial intelligence last century ago, and her book The Creative Mind: Myths and Mechanisms had been reviewed with a special issue in the journal of Artificial Intelligence

3.4 A process model of creative thinking based on Geneplore model and Wallas's four stages model

Fig. 3 shows the Japanese researchers' process model of creative thinking based on Finke's Geneplore model and Wallas's Four Stages Model, which defines a meta constraints as a mechanism to change the constraints explicitly [5]. During the preparation stage the cycle of the generative and exploratory phase is repeated and constraints are imposed at any time during the both phases. One steps to the incubation stage when no solutions come up to his/her problem. After some time, an insight or intuition is illuminated and generated through the meta constraints' changing. It supposed that this change of constraints causes a transform of the conceptual spaces, which is important for creativity as Boden puts it. Finally, the processes are repeated here for verification.

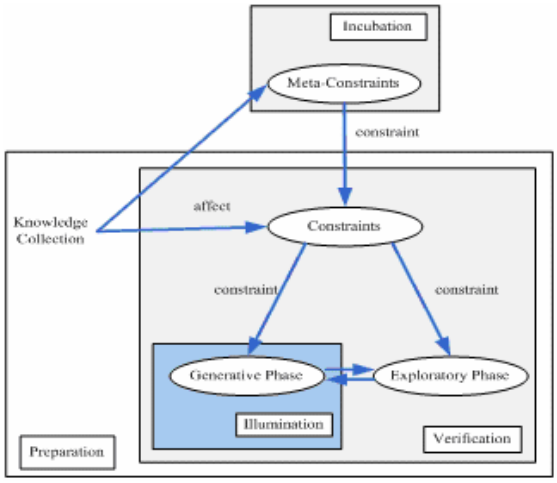

Fig. 3. A process model of creative thinking based on Geneplore and Wallas's four stages model

3.5 Creative space

Creative space is a network-like model of diverse creative processes with many nodes and transitions between them, which has been described by Wierzbicki and Nakamori in their book Creative Space. Intuitive, emotional, instinctive and mythical aspects of knowledge (tacit knowledge) are much more powerful sources of creativity than rational or explicit knowledge. Therefore, they think, most of creative spirals represent a form of interplay between diverse rational and intuitive or emotional aspects of knowledge in creative space[6].

Based on the SECI (Socialization – Externalization – Combination – Internalization) [7] Spiral which can be viewed as organizational creative spiral, Wierzbicki further proposed other three spirals: EAIR (Enlightenment – Analysis – Immersion – Reflection) Spiral; EDIS (Enlightenment – Debate – Immersion – Selection) Spiral; EEIS (Enlightenment – Experiment – Interpretation – Selection) Spiral. These spirals can be performed separately or combined into a Triple Helix of normal knowledge creation for academic research.

3.6 Group thinking model

Group thinking model is divided into three modes: individual thinking mode, cooperative thinking mode and collaborative thinking mode and applied by Advanced Telecommunications Research Institute International in an AIDE (Augmented Informative Discussion Environment) system. The concretely explains has been discussed in the reference [8].

Here, we do not introduce other mental models like Sternberg's three-facet model of creativity [9], Santanen's cognitive network model of creativity [10] any more. In a word, mental model is a useful way to represent and externalize the abstraction of creativity, at the same time, which is also the theoretical foundation of designing the computerized tools for creativity support.

4. Creativity Support System

As we had discussed, the research on creativity has two lines, one is about the definition and nature of creativity itself, and the other is building computerized tools support creativity, which be called as creativity support system (CSS). The aim of CSS is enhancing the participants' interest exploration, idea generation, concept formation and knowledge creation by revealing hidden structure behind the human's mental world.

Different types CSS have been designed and developed according the different thinking mode, which includes divergent thinking, convergent thinking and the two mixed thinking mode. Divergent thinking is the intellectual ability to think of many original diverse and elaborate ideas, usually starts from a common point and moves outward into a variety of perspectives. The goal of this type of thinking is to generate many different ideas about a topic. Convergent thinking is the intellectual ability to logically evaluate, critique and choose the best idea from altervatives. This type of thinking process supports group decision activities, which pays particular attention to knowledge synthesis, that is, a process of building consensus or making decisions. The emerged ideas and information through divergent thinking will be organized and structured using convergent thinking ways. Table 2 represents some typical CSS.

Next, our designed-independent CSS, group argumentation environment will be introduced.

5. Group Argumentation Environment

Group argumentation environment (GAE) as a man-machine cooperative CSS has been designed and developed to effectively and efficiently exploit human's implicit knowledge, externalize human's mental models, stimulate human's intuition, insight and creativity, and augment human's communication and collaboration skills. Based on group thinking model, GAE mainly supports brainstorming method. Some ideas are absorbed by AIDE. The following are versatile computerized aids for creativity support.

5.1 Visualized shared memory space

Visualized shared memory space represents the global structure of all the participants' joint thought, which provides a platform for people to develop new ideas through communication and collaboration with others in an environment where knowledge is created, nurtured and sustained. As shown in Fig. 4(a), the rectangular icons are utterance-objects, and the oval icons are keywords that have been articulated as attributes of utterance. Both the utterance and keywords are posted via the dialoguing area by the participants. The utterances are recorded simultaneously in the event record area with the temporal sequence.

Fig. 4(b) shows retrospective analysis which applies same mechanism as visualized shared memory space and provides participants to "drill down" the discussing process for visualized partial perspectives. Further analysis of pieces of discussion such as selected intervals of discussion or combination of any selected participants may be helpful to detect the existence or formulating process of a micro community and cquire further understanding about participants' thinking structure.

Table 2. Some typical creativity support systems

Systems	Developers	Thinking Mode	Method	Aims	Systemic Features
Inspirations[11]	Inspiration Software®,Inc. (USA)	divergent	Brainstorming	develop ideas and organize thinking	✓ Inspiration is the premier innovative software tools that inspire learners of all ages to brainstorm, organize, plan and create. ✓ Inspiration Professional Edition are designed specifically for diagramming, outlining, flowcharting, knowledge mapping, brainstorming, systems thinking and multimedia design.
Colab[12]	Stefik M. etc al. (USA)	divergent & convergent mixed	White Board	Brain Writing	✓ Write or edit in a window, and arrange it so that others could access and share the information. ✓ WYSIWIS
AIDE[13] (Augmented Informative Discussion Environment)	Nishimoto K. etc al. (Japan)	divergent	Multi-variant statistical analysis method	Conversation, Common Concept and Community Formation	✓ Informal conversation environment for collaborative concept formation. ✓ Use two-dimensional space to extend human's thought spaces during concept formation, to seamlessly integrate their daily activities such as individual thoughts and group meetings with the technique of information retrieval.
GRAPE[14] (Groupware for Acquiring Processing, and Evaluating knowledge)	Kunifuji S. etc al. (Japan)	convergent	KJ	knowledge acquisition support groupware	✓ A bottom-up type group decision support system. ✓ Support acquiring knowledge for a choice based on subjective judgment. ✓ Activate communications between users and acquires knowledge from the users. ✓ A tree structure is obtained by using Extend ISM. ✓ The evaluation sub-module is performed by using AHP.
Triz[15] (Teoriya Resheniya Izobretatelskikh Zadatch)	Altshuller G. (Russia)	divergent & convergent mixed	a theory of invention and problem solving	Theory of the Solution of Inventive Problems	✓ The theory was developed by analyzing patents. ✓ The theory attempts to formalize methods of creative thinking and provide generic innovation tools.
Global Think Tank[16]	Robert T. (Holand)	divergent	Brainstorming	Computer-Assisted Brainstorming	✓ It ensures a rich, multicultural variety of ideas and creative problem solutions. ✓ Fast "around the world, around the clock" brainstorming.

5.2 Automatic affinity diagramming and typical keyword detecting

From the whole visualized shared memory space to the partial retrospective analysis represents the top-down approach, which has been defined as the process of breaking down abstract concept (concerned issue) into concrete instances (utterances, keywords). Conversely, a bottom-up approach is the process of extracting abstract concepts from concrete instances. New idea generation and new concept formation are our research targets. For that, the automatic affinity diagram (sometimes called the KJ[17]) was developed to discover meaningful groups of ideas within a raw list. Usually it is used to refine a brainstorm into something

that makes sense and can be dealt with more easily. In GAE, an affinity diagram about the concerning topic discussed in the visualized shared memory space is automatically produced according to 2-D map, as shown in Fig. 4(c).

Similar to KJ method, centroidal algorithm based on K-means clustering method is also used here to detect the typical keywords at different given time, which is a further effectively help for participants to know the trends of the concerning topic. The number of typical keywords equals K which is an assumed number of centroids (clusters). In our example, as k = 3, three clusters are acquired as shown in Fig. 4(d) where the label for each cluster is as "visual", "analogy" and "meta-synthesis". Applying affinity diagramming and centroidal clustering embodies the man-machine interaction in argumentation process, which may be useful for participants to find some structures of the complex issues.

5.3 Original keyword provider recording

Boden claims P-creative if the person in whose mind it arises haven't had it before, no matter how many people may have had the same idea already. So, whether the submitted keywords evolve as the new concept or not, it is important and necessary to record the original keyword provider. During group argumentation, if you are the original keyword provider, the keywords which represent your ideas are your P-creativity results, as shown in Fig. 2(e). The function of record of original keyword provider in GAE system is to assist the users in finding what they had not noticed so far (P-creativity) that could lead them to really creative work at last.

The detailed introduction of other functions of GAE, such as evaluation of participation by calculation of eigenvectors about agreement matrix and dissimilarity matrix, facilitator agent, and information support for customized search, abstract and summarization, can see the reference [18-20].

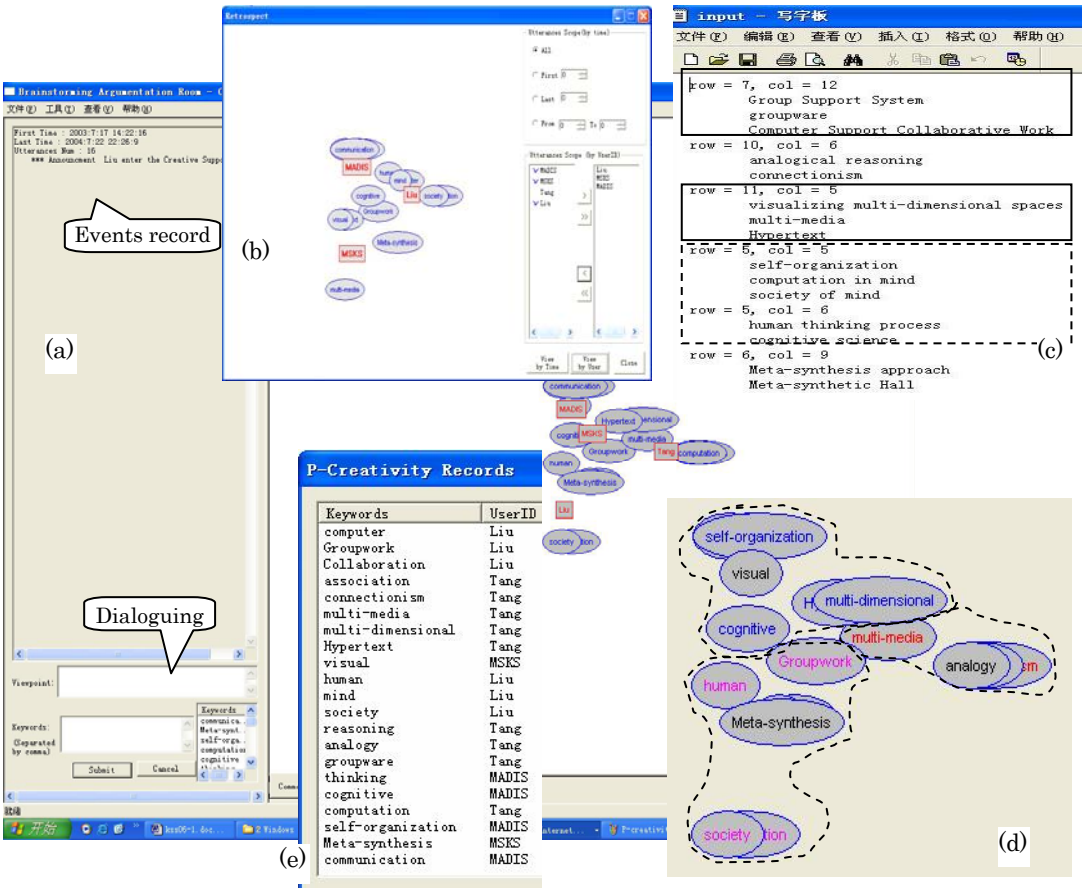

Fig. 4. Client window of GAE ((a) Main client window; (b) Retrospective viewer; (c) KJ editor; (d) Cluster analysis *K=3*; (e) Original keyword provider)

6. Conclusions and Future Work

In this paper, we focus on computerized support for enhancing human's creativity. Research on creativity and creative mental models together with computerized tools provides basis for our research. Our developed group argumentation environment as a CSS exhibits our ideas, which acts as a platform promoting individuals exchange ideas, stimulating their creativity and enhancing argumentation effects.

Our current work is still at very initial stage. Lots of further work are under exploration, such as better human-machine interaction, opinion synthesis in consideration of expert's background, and evolving process of keyword network to detect the pathway of knowledge creation, etc. More experiments will also be undertaken for verification and validation of GAE in practice.

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